NCDC Global Climate Laboratory Monograph
ORNL/CDIAC-69

Report of the International Workshop on Quality Control of Monthly Climate Data

National Climatic Data Center
Asheville, North Carolina USA
October 5–6, 1993

Sponsors:

National Climatic Data Center
National Oceanic and Atmospheric Administration
Asheville, North Carolina USA

Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
Department of Energy
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World Meteorological Organization
Geneva, Switzerland

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Executive Summary

The National Climatic Data Center (NCDC), the U.S. Department of Energy's Carbon Dioxide Information Analysis Center, and the World Meteorological Organization (WMO) cosponsored an international quality control workshop for monthly climate data, October 5–6, 1993, at NCDC. About 40 scientists from around the world participated. The purpose of the meeting was to discuss and compare various quality control methods and to draft recommendations concerning the most successful systems. The near-term goal to improve quality control of CLIMAT messages for the NCDC/WMO publication *Monthly Climatic Data for the World* was successfully met. An electronic bulletin board was established to post errors and corrections. Improved communications among Global Telecommunication System hubs will be implemented. Advanced quality control algorithms were discussed and improvements were suggested. Further data exchanges were arranged.

1. Introduction

1.1 Monthly climate data must rely on quality control techniques that are predominantly statistical. While the actual quality control may use numerical formulae or visual inspections of graphs, at the heart of most techniques are some basic statistical relationships. These relationships primarily fall into three categories: relationships of data elements to themselves (e.g., outliers from long-term means); relationships to nearby data (e.g., neighbor checks); and relationships to some other data parameter (e.g., sea level pressure to station pressure). The purpose of this workshop was to discuss these and other quality control techniques, to relate experience in applying quality control to data, and to organize cooperation in the production of quality control software.

1.2 The 2-day workshop was split into four sessions (see agenda in Annex I). The first session consisted of invited presentations. The second session was purely discussion. The third session included presentations of quality control software. The fourth and final session consisted of a discussion of what should be done in the future. The workshop was attended by people from many different agencies and from the following countries: United States, Germany, Australia, United Kingdom, Canada, Denmark, France, New Zealand, Russia, South Africa, Spain, and China. For a complete listing of participants see Annex II.

2. Session 1: Invited Presentations

2.1 Kenneth Hadeen, Director of NCDC, was the first speaker. He welcomed everyone to NCDC and discussed the importance of adequate quality control and quality assurance of meteorological data. However, he also stressed the fact that it is impossible to create *the* best data set.

2.2 Thomas Peterson of NCDC and conference coordinator initially discussed logistics of the workshop and then showed errors in data that can be difficult to detect. Examples included a station with large, frequent, systematic errors that could skew measurements of standard deviations; and a station with a sudden distinct diminishing of variance. (This problem was later explained by Phil Jones: For a number of years, French African stations reported in Kelvin. A temperature of 30°C would be about 300 Kelvin. To correct this "error," someone simply divided by 10, which produced data of approximately the right magnitude but with greatly diminished variance.) Looking at a graph of the complete time series of a station with this problem, it is clear that the data were bad, but in graphs of certain months, such as March, the data could appear reasonable. Lastly, graphs of temperature data were shown for two stations, Kuwait International Airport and Thamud, Yemen. Data for both stations looked reasonable. When overlaid, however, it was obvious that they were identical for 25 years, indicating a problem in at least one of the stations. Tom Peterson also handed out a sheet written by Tom Ross explaining how to access NCDC's *Monthly Climatic Data for the World* via internet (for more information, e-mail tross@ncdc.noaa.gov).

2.3 Helene Wilson of the NASA Goddard Institute for Space Studies, New York, gave a talk entitled "The GISS Global Temperature Analysis: Methods for Detecting and Resolving Station Data Inconsistencies," which described the process GISS goes through to identify erroneous data. Their techniques include merging data from a variety of sources, reconciling differences among the sources, looking for outliers from a serial perspective, and a numerical neighbor check. From the serial outlier perspective, they flag data that are deviations from long-term averages of more than five times a nonparametric rank-order statistic that is used instead of a standard deviation. This statistic is calculated by (1) ordering the nonmissing temperatures by magnitude, (2) disregarding the highest and lowest one-sixth of the ranked temperature values, (3) calculating an average from the remaining values, and (4) taking half the difference between the highest remaining value and the lowest remaining value. This statistic was identified as being nearly identical to the standard deviation if the data are normally distributed. One of the benefits of this approach is that outliers do not impact on this statistic the way they would on a standard deviation. Once a datum has been flagged as an outlier, an attempt is made to correct it: If the outlier can be brought to within two times the (non-) standard deviation by a sign change, then the sign is changed. The outlier identification flag is also removed from a temperature datum if the temperature from at least one of its closest neighbors deviates from its longer-term average by at least half the deviation of the suspect value from its long-term average.

2.4 David Cullum of the Hadley Centre for Climate Prediction and Research, Bracknell, UK, presented "The Quality Control Employed by the UK Met Office CLIMAT System." The U.K. Met Office has a surface CLIMAT data station archive of 3,100 stations and receives data from 1,330 stations each month. Their quality control includes outlier checks, neighbor checks, and multielement quality control flags such as mean sea level pressure insufficiently anticorrelated with precipitation or the number of days with rain exceeding the total number of millimeters of precipitation for that month. No data are actually changed during the automatic quality control process, but warning messages are generated indicating the magnitude of the discrepancies. After being inspected, data are manually overwritten and rearchived. A journal is kept with many station parameters, including latitude, longitude, normal values, and upper and lower confidence values for each element. Considerable concern was expressed about the decrease in the number of CLIMAT stations reporting.

2.5 Povl Frich from the Danish Meteorological Institute, Copenhagen, Denmark, spoke on "A Multi-Element Approach to Quality Control of the North Atlantic Climatological Dataset (NACD)." The data set Povl Frich deals with has many different elements, and some of the elements can be used to quality control other elements. For example, the number of days with precipitation is related to total monthly precipitation. The ultimate goal for a climate change detection data set is to have (1) a large number of stations, (2) a large number of elements, (3) for a long time, and (4) of high quality. Many researchers approach this goal by first pursuing a large number of stations for only one or two elements. NACD, however, has a large number of elements for a moderate number of stations and hence lends itself to this multielement quality control approach. Povl Frich also presented a proposed quality control approach for single temperature time series that would (1) use climatology to remove far outliers; (2) remove a linear trend if significant at the 95% level; (3) remove annual cycles by subtracting long-term averages for each month; (4) compute 3-month running averages to include natural memory; (5) compute the difference between #3 and #4; (6) sort #5 so that positive values are in ascending order and negative values are in descending order; (7) remove the highest values until the correlation coefficient stops improving or gets worse (this would allow removal of the worst outliers first, which can be important if resources are limited, and can give a quantitative assessment of when enough points have been flagged – see also paragraph 5.3.3.2); and (8) list these values for manual inspection.

2.6 Arne Spekat of the Institut fuer Meteorologie, Freie Universitaet, Berlin, Germany, discussed "Practical Aspects and Further Development of Quality Control for Monthly Temperature and Precipitation Data." He began by passing on a warning from Gary Larson that while two wrongs do not make a right, several wrong steps may lead to something that appears to be right. Arne Spekat spoke as a consumer of climate data because every month they put out a bulletin of climate charts for the northern hemisphere mainly based on CLIMAT data acquired over the Global Telecommunications System. Their quality control concern is with the past month's data and includes both spatial and serial quality control. For spatial quality control they use fields of temperature deviation from long-term means. Questionable temperature data are identified by averaging two to four neighboring values. If the deviation is 2°C or more without being justified by strong gradients or other signs of local extremes, a value is considered an outlier. To look for outliers from a historical perspective, they produce box and whisker plots for a station's time series. The value range between the first and third quartile, the inter-quartile range (i.e., the middle 50% of the data they want to quality control), is multiplied by 1.5 and stacked on top of the 75th percentile value and below the 25th percentile value. A datum is considered an outlier if it is outside that enlarged range. When the datum is outside triple the interquartile range, it is considered an extreme value. For precipitation data, monthly values are checked against the sum from daily reports whenever possible. In addition, they apply general plausibility and consistency checks such as whether the station report is correct to an order of magnitude (i.e., station reports in millimeters vs. tenths of millimeters). Arne Spekat ended with suggesting a CLIMAT quality control feedback mechanism: If a country routinely sends bad data we should inform them.

3. Session 2: Informal Discussion on Other Possibilities

3.1 Some groups calculate a standard deviation while others calculate a nonparametric rank test to use in determining outliers. One of the problems with using a standard deviation is that the presence of outliers in the population skews the value of the standard deviation. However, a rank test that bases its statistic on the distance between the 25th value and the 75th value might not represent the data well in stations with a bi- or multimodal distribution where 20% of the data might be far to the outside of the middle 50%. Generally, however, this was not a concern to most participants who felt that a nonparametric rank test, such as those described in paragraphs 2.3 and 2.6, was superior.

3.2 Thomas Peterson mentioned that he has been considering testing satellite-derived Normalized Difference Vegetation Index (NDVI) in quality control of precipitation data, particularly in remote areas such as the Sahel. No one present had any experience with using NDVI for quality control. Also, Peterson suggested the possibility of using deep-layer tropospheric sounding data derived from microwave satellites to quality control temperature data from remote stations. Again no one indicated any experience using microwave satellite data for quality control of surface temperatures, but Phil Jones questioned whether it was appropriate since microwave data measure a variable so different from what a thermometer in a shelter is measuring and because surface temperature is sometimes decoupled from the free troposphere. Jones suggested instead using satellite skin temperature measurements. However, these data also have their problems, such as the wavelength used is more susceptible to contamination by volcanic aerosols and clouds. Russ Vose emphasized that satellite measurements can only be used for "new" data, whereas the vast majority of data that the community works with is historical. No one else is considering using satellite data for quality control of surface data. However, some participants thought that sea surface temperatures (SST) may be useful in validating air temperature on isolated islands, though using SST to quality control coastal continental stations would likely present problems.

3.3 No one present mentioned that they were toying with any other unusual data fusion type quality control.

3.4 Several participants emphasized that the best source of additional data for monthly quality control was to use the daily data from the same station if one had that available.

3.5 Rick Schmoyer indicated that he developed a test to look for changes in the variance of a time series. This test, called a SCUSUM, would quickly detect problems such as that caused by improperly corrected Kelvin temperature reports mentioned earlier in paragraph 2.2.

3.6 Currently, when one group identifies errors in CLIMAT messages, there is no procedure to inform other groups using these data of the problems. That will now change: Joanne Logan of The University of Tennessee will set up an Internet bulletin board to be used by the Climate Analysis Center, the UK Met Office, the Free University of Berlin, NCDC, etc., to post errors and corrections to CLIMAT data (see Annex IV).

3.7 Some CLIMAT messages apparently do not cross oceans. William Angel of NCDC and David Cullum of the UK Met Office will cooperate to identify these problems and arrange a system, in conjunction with the WMO, to exchange these data so that all the CLIMAT messages received by any of the nodes in the United States, the United Kingdom, Australia, or Russia will be available to all researchers.

3.8 Arne Spekat suggested that it would be helpful to create a file of criticisms of existing data sets. However, no one volunteered to store and disseminate these criticisms.

3.9 If data are subjected to several quality control steps, it was suggested that perhaps the data should not be rejected unless they are flagged twice. This would prevent an outlier from a time series perspective from being rejected if the neighbor check indicated that all the nearby stations were extreme values too. Unfortunately, it would also prevent a station flagged by a spatial check from being removed unless it was also an outlier from a serial perspective. Some of these concerns could be addressed by the quality control algorithm (see also paragraph 5.3.4).

3.10 It was generally agreed that in both spatial and serial quality control, data should be flagged based on some normalized reference (standard deviation or related nonparametric rank order statistic) rather than an absolute reference frame (e.g., degrees C). If one flagged based only on how many degrees the value was away from a mean, tropical stations with little variability would have too few flags, while high latitude stations with high variability would have too many flags.

4. Session 3: Assessment of Current Quality Control

4.1 Steve DelGreco presented a videotaped demonstration of NCDC's operational GEA (Geographical Edit and Analysis) system. GEA is a geographically oriented quality control system for daily data from the U.S. cooperative observer network.

4.2 Art Leganchuk gave a demonstration of a Canadian PC-based quality control system.

4.3 Gerard Petit-Renaud gave a demonstration of his PC-based inhomogeneity testing program.

4.4 Phil Jones showed some transparencies of maps he uses for spatial quality control. Many other people use maps as well, because mapping is a quick way to prevent what one participant termed "horrendous errors."

4.5 Jon Eischeid described his quality control program that includes both spatial quality control and outlier quality control from serial perspective. Outliers from a serial perspective are identified similar to the way they are in the technique presented by Arne Spekat (paragraph 2.6): an interquartile range multiplier is used as a cut off. What the cut-off multiplier should be is determined by a graph of outliers flagged versus x times the interquartile range. This is an asymptotic graph and the value of x is subjectively chosen as the point where the slope approaches zero. For spatial quality control, Eischeid is developing a system to predict the value for a station based on data from nearby stations. Data would be flagged if the observed is too far from the predicted. The general opinion was that Eischeid's program is one of the more advanced quality control efforts currently being undertaken, and if a cooperative quality control effort comes out of the workshop, it would be helpful if his program would be the core of the effort.

5. Session 4: Planning Future Quality Control Cooperation

5.1 It was emphasized that when quality control software is written and made available to other researchers, it needs to be documented by a refereed journal article. This will enable a user to simply reference the article, and everyone will know what quality control the data has gone through.

5.2 Slava Razuvaev suggested that a small group should work towards documenting quality control procedures a monthly data set should be put through. This would be helpful to a group working on quality control of a data set and would lead to improved documentation of what quality control that data set has been subjected to. Russ Vose and Dale Kaiser agreed to join

Razuvaev on this project (see Annex III).

5.3 If Jon Eischeid's quality control work was going to form the basis of a cooperatively produced quality control software program, the participants in the final session had several suggestions that might make the quality control more effective. Most of these suggestions could be considered potential additions rather than substitutions for what Eischeid indicated that he is already working on. The suggestions include:

5.3.1 Adding SCUSUM and some of the other routines developed by Rick Schmoyer because they can expose special problems with the data that might not be noticed otherwise.

5.3.2 Remove a long-term climate signal prior to analyzing the time series data for outliers. This follows along the plan by Povl Frich (paragraph 2.5) who suggested removing a linear trend if significant at the 95% level. However, other ways to remove the long-term signal, such as a quadratic equation, a moving mean, or a moving median filter, might work as well or better. The purpose of this additional test is that if there is a strong, for example, positive trend in a 100 year time series (due to real climate change or artificial discontinuities), a positive outlier in the early part of the time series could easily be hidden by higher values later in the time series. Strong trends in time series data can also cause problems with spatial quality control if the long-term signal is not removed because one often deals spatially with anomalies from some mean or median value. For example, if a station has a strong positive trend due to a series of discontinuities, it is possible for all the early years to have negative anomalous values and all the later years to have positive anomalous values which do not reflect the real climatic deviations in the region. Obviously, serious problems can arise when dealing with historical or current spatial quality control if the nearby stations do not have the same trend due to inhomogeneities.

5.3.3 How to determine the point when enough outliers have been flagged is a question that was addressed several times during the workshop. Generally it was agreed that the number of flags one puts on the data (to be later hand-investigated) is related not only to the quality of the data and the use that data will be put towards, but also the time the researcher has to spend on quality control. Eischeid's approach is to flag outliers beyond a subjectively chosen interquartile range. Both Povl Frich and Russ Vose have worked on approaches that rank the outliers so that a researcher can start with the worst offender. However, Frich and Vose have different approaches for determining when to stop. It was generally agreed that either or a combination of the Frich and Vose approaches (see paragraphs 5.3.3.1 and 5.3.3.2) would be preferable to any fixed or arbitrarily adjustable cut off for determining when a datum should be flagged as an outlier.

5.3.3.1 Vose would stop when hand-investigation of the outliers indicated that very few genuine outliers were being flagged. For example, he would start by examining, say, those series with the ten worst outliers and counting the number of truly erroneous observations in the sample. Then he would look at those series with the next ten worst outliers and count the number of errors in that sample. After an adequate number of samples had been checked, he would plot the number of offenders in each sample against the sample number. Presumably, as the sample number increases, the percent of offenders should decrease, and hopefully the cutoff point (i.e., the point at which no more samples should be examined) would be intuitive and obvious.

5.3.3.2 Frich suggested a very different approach (see also paragraph 2.5). First, sort all the residuals or anomalous values (outliers are the most extreme anomalies or residuals) and pair the negative anomalies with the same sort number positive anomaly. That is, the smallest positive anomaly would be paired with the smallest (absolute value) negative anomaly, the second smallest positive with the next negative, right on up to pairing the most extreme positive and negative outliers. We can then plot these pairs with the x axis being the negative anomalous value and the y axis the positive anomalous value. The resulting plot would probably be a fairly straight line until strange outlier values crop up. A linear correlation coefficient would be quite high. Frich proposed that one would continue to flag and remove the highest ranking outlier values until a correlation coefficient stops improving or gets worse. This may be able to provide a clear objective way to determine how many outliers to flag.

5.3.4 David Stooksbury indicated that when looking over precipitation data from the midwestern U.S. in the wake of this summer's very heavy precipitation, he found many stations with data that could easily be flagged as extreme outliers and an isolated station with average precipitation. The error in that case was not the outliers but rather the station reporting average precipitation. The quality control system should be able to examine the data spatially and flag this type of error.

5.3.5 Concern was expressed that sometimes a whole country will report bad data (such as all the precipitation data being off by a factor of 10). Spatial checks should, therefore, also take country borders into consideration.

6. Epilogue

6.1 Slava Razuvaev, Russ Vose, and Dale Kaiser have compiled a list of quality control procedures that they would recommend for all data sets. They have routed it to other researchers for comments and suggestions. Generally it has been well received and should serve as a valuable checklist for people working on quality control of a new data set. The current version of their checklist is added here as Annex III.

6.2 Joanne Logan has arranged for a CLIMAT users bulletin board on Internet. The format is an unmoderated electronic mail list. Any message sent into the list is rebroadcast to all subscribers. To subscribe to the list, send an e-mail message to

almanac@awis.auburn.edu

Put whatever you want as the subject. In the body of the message put the command

subscribe climat

and send the message. You will get a confirmation message by return e-mail. For more details see Annex IV.

6.3 The prime goal of this workshop was to produce improved quality control software. While some researchers will continue to work on their own quality control endeavors, Russ Vose, Rick Schmoyer, William Angel, Povl Frich, and Thomas Peterson intend to work cooperatively to bring about the improved and expanded quality control system that was discussed at the workshop. This quality control software would be written for the Global Historical Climatology Network, the North Atlantic Climatological Data Set, and the Monthly Climatic Data for the

World data sets, but be available to anyone who would request it.

6.4 Bartolome Orfila has followed up on the workshop with a proposal for exchanging historical data from CLIMAT reporting stations. Improved historical data would allow a more accurate assessment of what values should properly be considered erroneous outliers.

Workshop Agenda

Session 1: Tuesday, October 5, 8:45-11:45 AM, NCDC Room 289

"Welcome"

Kenneth Hadeen, Director, National Climatic Data Center, Asheville, NC USA

"The Nature of the Problem Before Us"

Thomas Peterson, National Climatic Data Center, Asheville, NC USA

"The GISS Global Temperature Analysis: Methods for Detecting and Resolving Station Data Inconsistencies"

Helene Wilson and Reto Ruedy, NASA Goddard Institute for Space Studies, New York, USA

"The Quality Control Employed by the UK Met Office CLIMAT System"

David Cullum, Hadley Centre for Climate Prediction and Research, Bracknell, UK

Break

"A Multi-Element Approach to Quality Control of the North Atlantic Climatological Dataset (NACD)"

Povl Frich, The Danish Meteorological Institute, Copenhagen, Denmark

"Practical Aspects and Further Development of QC for Monthly Temperature and Precipitation Data"

Arne Spekat, Institut fuer Meteorologie, Freie Universitaet, Berlin, Germany

Session 2: Tuesday 1:30-4:30 PM, NCDC Room 289

Informal discussion of other possibilities

i) What other groups have been doing
ii) What individuals have been planning on trying
iii) Ideas the discussions today have inspired

Session 3: Wednesday October 6, 8:45-11:30 AM, NCDC Room 289

Cooperative development of QC software: Current assessment

i) Demonstrations
   a) A video of the GEA System, National Climatic Data Center, Asheville, NC USA
   b) A PC Based QC System, Art Leganchuck, Atmospheric Environment Service, Downsview, Ontario Canada
ii) Software and/or algorithms available now
iii) Documentation

Session 4: Wednesday 1:30-4:30 PM, NCDC Room 289

Cooperative development of QC software: Planning

i) Organizing future algorithm and software development
ii) Apportionment of tasks
iii) Timetables
iv) Future communication options

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Checklist for Quality Control of Monthly Climatic Data

From a data management standpoint, a quality control procedure consists of tests designed to ensure that climatological data meet certain standards. In other words, quality control implies looking for errors in data. These "errors" take many forms, ranging from magnetic media problems to outliers to data gaps to time series inhomogeneities. Given the wide variety of data quality problems, it is not surprising that numerous techniques have been developed to identify them. Unfortunately, no standard quality control methodology exists. In fact, not even an inventory or overview of such methods is available. The present "checklist" serves, in a way that might best be described as a "first approximation," to rectify this oversight.

A wide variety of problems are addressed in this checklist. However, not every problem is relevant to all individuals or all data sets. The type of quality control procedure one chooses will ultimately depend upon the intended application of the data set one is using. In general, a distinction can be made between the compilation of a new data set and the analysis of a preexisting data set. Typically, more indepth quality control checks should be applied in the former case, as a new archive is being prepared for use by a community of researchers. In the latter case, checks are done by the end-user to verify the accuracy of a data set that may only be used a few times. Regardless of the application, two important points should be kept in mind:

1. The quality control procedure that is implemented should always be documented. This ensures that others who receive the data set know exactly what (if any) problems have been identified and what (if any) checks need yet to be performed.

2. In general, suspect or erroneous values should be flagged instead of set to missing because the erroneous values themselves may contain information about the "correct" values. Exceptions might include problems such as the presence of character values (e.g., asterisks) in numeric fields or numbers that exceed the space allocated for the variable itself. If "corrected" values are available, they should be supplied separately.

One final point should be kept in mind. If a data set is to be used by a large number of researchers or over a long period of time, it should probably be revised at specified intervals (e.g., every year). In each revision, quality control procedures should be applied to the entire data set, not just to the newly acquired data, because certain statistics (e.g., means) will change with the addition of the new data. In addition, in "operational" settings where forecasts or analyses are performed regularly (e.g., monthly), data sets may need to be "updated" between major revisions. In the interest of time, only the newly acquired data probably needs to be quality controlled. Likewise, checks should, for the most part, focus on "gross data problems."

Without question, this checklist falls far short of its intended application. The authors have a sincere desire to correct its problems. Feel free to contact us in that regard at any time.

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1. Gross data problems
   - Examine the files for the presence of data processing errors (e.g., truncation of lines), corruptions that might have been introduced in transport (e.g., unreadable characters), and any other problems that might stem from machine-readable media.
   - Verify that the actual format of the files agrees with the expected format.
   - Determine whether or not the files contain the correct number of stations and whether or not the station numbers in the files match supplied metadata.
   - Check for impossible values (e.g., meaningless dates, temperatures exceeding known world record values, negative rainfall totals, etc.) using basic thresholds.
   - If the data set has been quality controlled previously, check for undocumented missing value indicators and flag codes.
   - If applicable, determine whether or not the files are properly sorted.

2. Completeness of station records
   - Determine whether or not the first and last year of record for each variable at each station agrees with supplied metadata/documentation. If possible, also compare the period of record for each station to the period of record for that same station in another data set. This will indicate whether or not all of the data for a particular station has been acquired.
   - Compute the percentage of data missing by variable and station; determine whether or not missing data values are concentrated in certain months or years and whether or not the data gaps (if any) have a clear cause (e.g., war prevented collection of observations).

3. Subtle data problems
   - Check for cases in which the same data value occurs for several consecutive months in one or more years.
   - Check for cases in which consecutive years have exactly the same data.
   - Check for cases in which the same data value occurs in the same month of several consecutive years.
   - Check for cases in which a month with missing data was "left out" rather than set to missing, causing all subsequent data values to be placed in the preceding month (e.g., October's data value would be listed under September).
   - If possible, check for the presence of duplicate stations (i.e., two stations with the same station number or the same data listed under two different station numbers). Depending upon the level of sophistication, this check could be either very simple or very complex.
   - If possible, compare monthly values to daily values for consistency.

4. Outliers from a serial perspective
   - Check for erroneous values on a month-by-month basis by using regional climate thresholds (e.g., 1 meter of rain in the Sahara), thresholds derived from parametric statistics (e.g., n standard deviations away from the mean) or nonparametric statistics (e.g., n times the interquartile range), etc.
   - Check for erroneous values by comparing each monthly value to values in surrounding months (e.g., by computing the difference between the average of the surrounding months and the current month).
   - Check for discontinuities, such as changes in the mean (e.g., by using the CUSUM

statistic) or changes in variance (e.g., by using a scale-change analog of the CUSUM statistic).

- In general, "serial" outliers should be identified by examining the original, unmodified time series. However, if the series has a significant long-term trend (e.g., linear, quadratic, etc.), it may be appropriate to remove that trend prior to checking for outliers. Making the *a priori* assumption that a series has a trend is not suggested; rather, the series should first be tested (both statistically and visually, if possible) for the presence of the trend before detrending the record itself.

5. Outliers from a spatial perspective
    - Check for erroneous values on a month-by-month basis by comparing each observation to observations at neighboring stations; comparison can be accomplished in several ways (e.g., by using the visual method proposed by Phil Jones of the University of East Anglia; or by using the automated, nonparametric method proposed by Jon Eischeid of the Cooperative Institute for Research in Environmental Sciences).
    - Check for mislocated stations by comparing the long-term average at a station to the averages at neighboring stations; comparison can be accomplished in the same manner as described previously.
    - In general, as with the "serial" checks, these "spatial" checks should be performed on the original, unmodified time series. Proceed with caution if detrending is necessary.

CLIMAT Users Electronic Mail List

One of the ways we decided we could improve quality control of CLIMAT data would be to set up an electronic bulletin board where users of CLIMAT data could post error messages and other information. Joanne Logan investigated many options and recommended that we go with an unmoderated electronic mail list where anyone with Internet e-mail could subscribe to it. In response to Logan's inquiries, Rodger Getz, NOAA/National Weather Service, SE Ag Weather Service Center, Auburn University, Alabama (rgetz@awis.auburn.edu), graciously agreed to set us up on his Almanac.

To subscribe to the CLIMAT data users list, send an e-mail message to

almanac@awis.auburn.edu

Put whatever you want as the subject. In the body of the message put the command

subscribe climat

and send the message. By return e-mail you will get a confirmation message. You may end your subscription in a similar manner by sending the message

unsubscribe climat

If you want to learn more about almanac, send the command

help

as was done with the subscribe command.

To post a message to all climat subscribers, send the message to

climat@awis.auburn.edu

and all subscribers will get the message.

While the original inspiration for this e-mail list was to improve quality control of CLIMAT data by improving communication between people performing quality control on CLIMAT data, we expect that error messages will not be the only CLIMAT user-related postings. Rodger Getz informs us that the almanac software, which was developed by Oregon Extension, will also allow the automated retrieval of documents stored on his system. If, for example, someone had some program code or a document that they wanted to make available, this could be stored on his system. Climat subscribers would be informed of the availability of the document and provided the instructions for getting the information. The user could get the document if it was of interest. The alternative, sending the document to all CLIMAT subscribers via e-mail would result in a large amount of e-mail traffic, some of which would not be needed. The number of documents, programs, etc. that he can keep on line will depend on disk space and other resources. Most of these computer resources have been provided through grants from Auburn University.

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